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Supporting documents are attached to the report as separate files (MS Word, PDF, HTM).

14. ABSTRACT

The objective of this Lecture Series was to offer a review of the major investigation tools used in hypersonic research. It presented the typical aerothermodynamics phenomena occurring in hypersonic flight in parallel with the ground testing and CFD capabilities tailored for their study. The idea was to provide engineers and researchers with a critical view on the experimental tools and numerical models used in aerospace research for aircraft design. Their range of validity was addressed as well as their limit and capabilities. It aimed also to define the needs for development of experimental facility and flow diagnostics as well as modeling efforts. A specific session pointed out the recent research axis dealing with validation and verification for hypersonic studies. The note constituted a reference on the advanced research tools developed for re-entry and cruise vehicle design.

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Aerothermodynamic Design, Review on Ground Testing and CFD

(Conception aérothermodynamique, revue sur les essais au sol et dynamique des fluides informatisée)

Papers presented at the AVT-186 RTO AVT/VKI Lecture Series held at the von Karman Institute, Rhode St. Genèse, Belgium, 29 March – 1 April 2010.

Edited by: O. Chazot, K. Bensassi

von Karman Institute for Fluid Dynamics, Belgium

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The Research and Technology Organisation (RTO) of NATO

RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote co-operative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective co-ordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also co-ordinates RTO's co-operation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of co-operation.

The total spectrum of R&T activities is covered by the following 7 bodies:

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier co-operation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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Aerothermodynamic Design, Review on Ground Testing and CFD

(RTO-EN-AVT-186)

Executive Summary

The Lecture Series focus on the presentation of ground testing methodologies and facilities as well as the numerical tools currently involved for the design of aerospace vehicles. The course addressed four main points: simulation methodologies and capabilities of hypervelocity facilities; their operation and main applications for re-entry vehicle design; the measurement techniques applied for these reacting high speed flows; and the CFD tools dedicated to the design of high enthalpy facilities and those mostly used for the investigations of aerothermodynamic phenomena.

All the lecturers are well recognized in their field of expertise and succeed to share at best their large experience through detailed presentations and lecture notes.

Hypersonic ground testing simulation is first presented, including real gas effect. Typical capabilities and limitations are discussed for high enthalpy facilities. Their operations and applications are illustrated with NASA Ames EAST and Ballistic facilities, CUBRC expansion tubes, ITAM impulse wind tunnels and DLR HEG shock tunnel. Fast response probes and unsteady measurement techniques are exposed as well as non-intrusive diagnostic tools, like spectroscopy from VUV to NIR, and thermal imaging. Their contribution for aerothermodynamic database and reference test case are also reported.

The use of numerical tools is presented, in a first step, with their utilization for the design of high enthalpy facilities and the corresponding predictions of performances. In a second step the coupling approach between experimental and numerical investigations, typical of hypersonic research, is shown for the specific case of HEG facility. Finally the current CFD challenges regarding aerothermodynamic simulation and validation for planetary re-entry studies is exposed.

Conception aérothermodynamique, revue sur les essais au sol et dynamique des fluides informatisée (Computational Fluid Dynamics – CFD)

(RTO-EN-AVT-186)

Synthèse

La série de conférences s'est focalisée sur la présentation des méthodologies et des installations d'essais au sol ainsi que sur les outils numériques actuellement utilisés pour la conception des véhicules aérospatiaux. La session a traité quatre principaux points : les méthodologies de simulation et les capacités des installations d'hypervélocité ; leur fonctionnement et leurs principales applications pour la conception des véhicules de rentrée atmosphérique ; les techniques de mesures appliquées pour ces écoulements réactifs à haute vitesse ; et les outils de CFD prévus pour la conception d'installations à haute enthalpie et ceux utilisés fréquemment pour l'examen des phénomènes aérothermodynamiques.

Tous les conférenciers étaient pleinement reconnus dans leur domaine d'expertise, et réussirent à faire partager au plus haut point leur grande expérience au travers de présentations et de notes.

La première présentation a porté sur la simulation des essais hypersoniques au sol incluant l'effet réel des gaz. Les capacités et les limitations particulières des installations à haute enthalpie ont été débattues. Leur fonctionnement et leurs applications ont été illustrées par les installations de l'Ames EAST et Ballistic de la NASA, les tubes d'expansion CUBRC, les souffleries à impulsions ITAM et les tubes à choc DLR HEG. Les sondes à réponse rapide et les techniques de mesures instables ont été présentées ainsi que les outils de diagnostic non intrusifs, comme la spectroscopie des VUV aux NIR, et l'imagerie thermique. Leur contribution aux bases de données aérothermodynamiques et aux cas d'essais de référence ont aussi été mentionnées.

L'utilisation des outils numériques a été exposée et concernait, dans un premier temps, la conception des installations à haute enthalpie et les prévisions associées de performances. Dans un second temps, l'approche conjointe des recherches expérimentales et numériques, typique de la recherche hypersonique, a été présentée dans le cas spécifique des installations HEG. Enfin, les défis actuels de la CFD concernant la simulation et la validation aérothermodynamique destinées à l'étude de la rentrée atmosphérique ont été exposés.